No. III.

IMPROVED ELECTRO-MAGNETIC APPARATUS.

The LARGE SILVER MEDAL *and* THIRTY GUINEAS *were this session presented to Mr. W.* STURGEON, 8, *Artillery-place, Woolwich, for his Improved Electro-Magnetic Apparatus. A set of which has been placed in the Society's Repository.*

MR. MARSH'S apparatus, for the same purpose as Mr. Sturgeon's, was rewarded by the Society in the session before last. The battery, consisting of plates presenting eight surfaces of about a square foot each, and weighing from twelve to thirteen pounds, was the smallest that had at that time been applied to electro-magnetic researches. The rest of his apparatus, with few exceptions, was such as had already been used by Ampére, Sir H. Davy, Mr. Barlow, Mr. Faraday, and others, fitted together in a very convenient way, and stowed in a box, which, with the battery, made a package sufficiently portable.

Mr. Sturgeon's apparatus is even more portable than Mr. Marsh's, and (the moving parts being at the same time larger) is better fitted than that for the use of the lecturer.

The battery is similar in construction to Professor Hare's calorimotor, and consists of two fixed, hollow,

concentric cylinders of thin copper, having a moveable cylinder of zinc placed between them. Its superficial area is only 130 square inches, and it weighs no more than 1lb. 5oz. It is moveable on an upright metallic rod, like a laboratory lamp, and may therefore be adjusted to any convenient height. It will not hold more than about a pint of liquid, which should be composed of one part nitric acid, and eleven parts water: it is charged with the greatest ease, by merely pouring in the liquor from a common lipped jug. A farther advantage of the construction is, that after every experiment the liquor may be returned to the jug, while preparations are making for the next, by which the battery, when wanted, is in a state of high activity, and is undergoing no deterioration in the interval between one experiment and another.

A farther point of novelty is, that Mr. Sturgeon has very judiciously chosen to have a small galvanic power, assisted by a strong magnetic power, rather than the reverse, as is usually the case. This has enabled him greatly to economize in the size of his battery, and in the cost of acid to excite it, while the increased magnetic power is obtained at a small first expense, and needs no renewing.

SIR, No. 9, Artillery-place, Woolwich.

THE science of electro-magnetism, although so generally interesting, yet (comparatively speaking) appears to be very little understood. This latter circumstance is probably, in a great measure, owing to the difficulty of making the experiments, and the great expense attending

the process; for, besides the first price of a large battery, considerable expense in acid must always attend its excitation, whenever an experiment is attempted. Large batteries are always attended with difficulty of management, and the great quantity of hydrogen evolved during the process renders the use of them extremely inconvenient to the operator. These are evidently great obstacles to the experiments being often repeated, and to the science being generally known. Another, and perhaps no less obstacle to the advancement of this interesting science, is, that the experiments being hitherto exhibited on so small a scale, are by no means calculated to illustrate the subject in public lectures; for when the experimenter succeeds even to his wishes (which is not frequently the case), the experiment can only be seen by a very near observer, and the more distant part of the auditory are obliged to take for granted what they hear reported (from those persons who are more favourably situated), of some of the most interesting facts, which they, from their distance, are unable to witness.

With a view of removing, in some measure, these apparently formidable obstacles in the progress of this infant science, I have devoted a considerable portion of time, labour, and expense, in repeating several of the experiments, under various circumstances, and with various forms and sizes of batteries. I have likewise instituted a series of experiments, for the purpose of discovering, if possible, if any particular ratio of galvanic and magnetic power was absolutely necessary to be observed in the process of electro-magnetism. If no particular proportion of those two powers was essential, then it appeared highly probable that an increase of magnetic power might com-

pensate for a deficiency of the galvanic, and thereby render the use of large galvanic batteries quite unnecessary, an object which I considered both interesting in its nature, and, by reducing the expense, and facilitating the process, exceedingly desirable to the experimenter; and I am happy to state, that my labours were no ways abortive, for instead of electro-magnetic phenomena depending on powerful galvanic, and feeble magnetic force, as had till then been practised, I found, during that inquiry, that the galvanic force may be reduced to almost any degree, provided the magnetic be sufficiently powerful. This discovery led me to the use of powerful magnets, and small galvanic batteries, for with small magnets the experiments can never be made on a large scale, although the galvanic force be ever so powerful; and as minute and delicate experiments are not calculated for sufficiently conspicuous illustration in public lectures, I considered that an apparatus for exhibiting the experiments on a large scale, and with easy management, would not only be well adapted to the lecture room, but absolutely valuable to the advancement of the science. Upon this principle I have constructed a complete set of instruments, which, from their superior magnitude, and peculiar arrangement, are, in my humble opinion, and by the certificates I have been honoured with, are, in the opinion of gentlemen whose judgment I presume will ever be held in the highest estimation, well adapted for the illustration of the subject, either in the private study or public lecture room.

It will be understood from what I have already stated, as well as from an inspection of the instruments, that the mode which I have taken for the production of electro-

magnetic phenomena is more simple in its management, less expensive in the process, better calculated for the illustration of the subject, and the reverse of that which has hitherto been used, and which, by its almost entire dependence on the tedious and expensive process of galvanism, has considerably retarded and obscured this new and interesting science; for whenever an experiment was not attended with the anticipated success, the failure was generally attributed to an insufficiency of galvanic power; and in order to increase the effect, it appears that the experimenter had no other means of accomplishing his object, than by augmenting the power of his battery, or by reducing the size and increasing the delicacy of his other apparatus, the magnetic power being either entirely lost sight of, or regardlessly neglected, as if no ways materially concerned in the process.

I have found, however, by the above-mentioned course of experiments, that the magnetic force is as essential as that of galvanism to the development of electro-magnetic phenomena; and the apparatus which I now submit to the attention and impartial consideration of your valuable Society, acting on the principle of powerful magnetism and feeble galvanism, will, I trust, be found more eligible and efficient than any other that has yet been brought before the public.

I am, Sir,

&c. &c. &c.

W. STURGEON.

A. Aikin, Esq.
Secretary, &c. &c,

CERTIFICATES.

Royal Military Academy, Woolwich Common,
9th May, 1825.

SIR,

As I understand that Mr. William Sturgeon proposes to submit his galvanic battery and electro-magnetic apparatus to the consideration of the Society for the Encouragement of Arts, &c., I take the liberty of recommending them to your favourable consideration, although I have not the honour of being personally known to you. Since the first discovery of the action of the galvanic circuit on the magnetic needle, I have witnessed all the principal phenomena connected with electro-magnetism, as exhibited by batteries and apparatuses of different constructions, and have no hesitation in saying, that the battery and apparatus of Mr. Sturgeon are most admirably calculated for exhibiting all these phenomena in the most striking manner, and that they afford peculiar facilities for investigation in this most interesting science. The expense attending the purchase and use of large galvanic batteries, the difficulty of keeping them in powerful action, and the inconvenience of using them, except in laboratories, must all tend to retard the progress of a science, which has opened a new field for inquiry; and as the battery and apparatus of Mr. Sturgeon are free from all these objections, I consider that, by rendering them public, the cause of science is promoted, and that he is deserving of every encouragement for their invention and successful application.

I am, Sir,

&c. &c. &c.

S. H. CHRISTIE, M.A.

A. Aikin, Esq.
Secretary, &c. &c.

Royal Military Academy, Woolwich,
May 9th, 1825.

SIR,

I BEG leave to introduce to the favourable notice of the Society, Mr. William Sturgeon, a resident of this town, who has for some time devoted himself most sedulously to the improvement of apparatuses for the development and exhibition of the properties of electro-magnetism. He wishes to solicit the patronage of your valuable Institution to a new *battery* of his invention, which, while it is very far smaller than any other of which I have heard, is very efficacious, and at the same time remarkably calculated to facilitate the experiments. Mr. Sturgeon has also, in my judgment, greatly improved several other classes of apparatus employed in this interesting department of research, and constructed them upon a scale which renders the experiments susceptible of pleasing, and successful exhibition to a large auditory. He will regard himself as highly honoured, by permission to exhibit them before a committee of the Society; and I cannot but believe, that if he be so honoured, his talents and ingenuity, tending, as they have done, to most curious and pleasing results, will entitle him to favourable consideration and an appropriate reward.

I am, Sir,

&c. &c. &c.

OLINTHUS GREGORY,
Professor of Mathematics.

A. Aikin, Esq.
Secretary, &c. &c.

HAVING read the above certificate of Dr. Gregory, and that of Mr. Christie, I have no hesitation in adding my testimonial to every thing there stated.

PETER BARLOW.

Reference to the Engraving of Mr. W. Sturgeon's Electro-Magnetic Apparatus.—Plates III. *and* IV.

PLATE III. Fig. 1. A perspective view of an apparatus to show the revolution of a magnet round its own axis. *a a* the two galvanic apparatuses on their stands *b b*, they are acting on the magnet N S, by means of the connecting wires *d d d d*; both their copper poles C C are applied to the equator *e* of the magnet, while the zinc pole Z of one is applied to the north pole N, and the zinc pole Z of the other is applied to the south pole S of the magnet. A wire *f* is soldered on to the magnet, and bent down at one end to dip into the circular trough *e* to form the equatorial connection: and as all the connections are made by mercury and amalgamated wires, the end of this wire is amalgamated, and mercury put into the trough: all the little cups Z and C are also amalgamated at the bottom, and contain mercury; the bottom wires of the zinc and copper poles are likewise amalgamated to dip in connecting cups when wanted. The magnet has brass wire centers on which it turns, that at the north pole stands in a cup Z with mercury; and the other at the south pole enters the amalgamated hollow in the screwed end of the upper connecting cup Z. When the connections are made, as above described, on pouring in dilute nitric acid into the troughs *a a*, the magnet will revolve in the way shown by the arrow; but on changing the connections, by applying the copper wires to the poles, and the zinc ones to the equator, it will revolve the contrary way; here the magnet only forms the connection between the electric poles, and revolves around, or with the current which is conducted by it. *g g g* is the stand which

supports the magnet; the equatorial trough *e* is made moveable on the pillars *g g*, and is fixed by the screws *h h*.

Fig. 2. A bird's-eye view of the same, without the stands *b b* and *g*. The galvanic troughs *a a* are copper, and cylindrical, having a smaller split cylinder of copper, soldered within to increase the copper surface; the intermediate cylinder in each trough is zinc, it has three cork feet, cemented to the bottom edge to prevent contact with the copper, and two pieces of cork *i i* cemented at top for the same purpose; *e* the annular trough.

Fig. 3 shows the magnet separate.

Fig. 4. A wooden cover; one is fitted to each trough *a a*, to prevent the ebullition of the acid from damaging the apparatus.

Figs. 5 and 6. A side and front view of a circular metal disk, made to revolve between the poles of a horse-shoe magnet; the disk is amalgamated round its edge, and dips into a little mercury contained in a hollow *j* of the stand, the centers *k k* on which it turns, and the hollows that receive them in the forked support *l l* are amalgamated; the screw *m* allows the disk to be adjusted, and fixed so as only just to touch the surface of the mercury. A horse-shoe magnet N or N S shown by dotted lines, is laid on the stand, then one of the troughs *a* of fig. 1, is to be adjusted on its stand *b*, till its bottom wire Z dips into the connecting cup Z, forming the zinc communication, and a connecting wire *d* with bent ends, is to dip into the copper connecting cup C of the trough, and into the cup *c* of the disk; the communication of the poles being thus made, (the current passes from Z, through the mercury *j*, into the edge of the disk, and through its centers *k k* into the fork *l l*, and up to the cup *c*) the

disk will then revolve as shown by the arrow. By reversing either the poles of the magnet, or the electric poles, the revolution of the wheel is reversed; but if both are reversed, the revolution will continue in the same way as at first. The six rays are painted on the disk, merely to render the revolution visible at a greater distance.

Fig. 7. A stand supporting a needle between two conducting wires *o o* and *p p* to show the different effect of electricity on the needle when passing above or below it; the cup z is common to both, but the other ends have each a separate cup c c: when the electric current passes along the upper wire, *p p* the needle takes the position as shown in fig. 8; but on lifting the connecting wire out of the cup *p* c and putting it into the cup *o* c, the current passes through the under wire *o o*, and the needle immediately goes round to the position indicated in fig. 9; then if you watch the motion of the needle, and keep alternately transferring the wire out of one cup into the other, keeping time with the needle, you may bring it into the most rapid revolution that you can possibly keep time with.

Plate IV. figs. 19 and 20, show a side and front view of a dipping needle, mounted between two wires, *o* and *p*; they are here placed in the direction of the dip, but the quadrant *i* allows them to move one quarter round, or to the equator of the magnet, as shown by dotted lines. In their present position the needle will deviate, as figs. 8 and 9, plate III.; and it will be seen the needle cannot take a position quite at right angles to the wire, owing to the terrestial magnetism drawing it on one side; but when the wires are carried round to the dotted position, fig. 19. plate IV., the needle remaining as it was, so as to be at

right angles to each other, then on passing the current from z through the wire *o o*, no effect will appear to take place, the needle is only more confirmed to its position, but on passing it through *p p*, the needle goes round, and dips with its south pole. The wire passes through the wooden cup z, but the two ends of it *p* and *o* only just enter their respective wooden cups c c; these wooden cups are placed at an angle of 45° to the horizon, so that in either position they are similar, and will hold mercury enough to make the contact.

Plate III. fig. 10, shows an arrangement for making a cylinder revolve, by applying a battery of magnets to the outside. The cylinder and stand are in section to show the support.

Fig. 11 is a bird's-eye view of the same apparatus, the cylinder being removed, and its place shown by a dotted circle; the middle portion *q* contains mercury, which also flows in a very narrow arm to the side where the magnets are placed. The sides of this narrow arm are so low that the convex surface of the mercury rises above them, and the edge of the cylinder, which is amalgamated, passes over, as shown by the dotted circle, and keeps in contact with the convex surface of the mercury without touching the sides of this little trough. The cylinder, fig. 10, has a sharp point in its crown, by which it hangs freely on the top of the central wire *r*; this wire fits into a pipe or hole *s* in the stand, and the mercurial trough *q* being varnished, prevents this axis from forming a communication. There is also a little connecting cup *t* for mercury on the top of the cylinder, into which the screw of the upper connecting cup c dips just enough to touch the mercury; *v v* is a wooden stand holding six magnets, the

north poles of which are placed near the cylinder on the side that dips into the mercury; then on making the galvanic communication with Z and C, the current passes through the wire of Z into the mercury *q*, and out of the mercury up that side of the cylinder opposed to the magnets, and meets the copper pole C at top. Now the magnets are continually propelling that portion of the cylinder which forms the connection, and as the succeeding portions continue to form the connection with the mercury, only opposite to where the magnets are placed, they are as continually propelled, and thus a revolution is produced; the arrows show the direction of the motion, and changing the poles changes the direction.

Fig. 12. *w w* shows the arm which supports the upper conducting cup, it fits into the pipe *x*, which is screwed to the foot.

Figs. 13 and 14. A front and side view of a stand with two connecting cups Z and C made of wood, in which the bent iron wire wound round with copper wire is supported by the two copper wire ends. On making the galvanic connection through the copper wire, the iron wire becomes a strong horse-shoe magnet, and will support a heavy bar of iron as *y* fig. 14; but on lifting the connecting wire *d* fig. 13, out of the cup Z, the weight immediately drops, and on restoring the connection, the power is restored, then if you change Z for C, it will change N for S, or if you only wrap the copper wire about the iron wire, as a right threaded screw instead of a left one, as in the drawing, it will change N for S. This is explained by what takes place in figs. 7, 8, and 9.

Plate IV. fig. 1. Another copper wire fitting the stand,

Plate III. fig. 13. This arrangement communicates

magnetism to hardened steel bars, as soon as they are put in, and renders iron wire within it magnetic during the time of action, it only differs from fig. 13 in being straight, and thereby allows the steel or iron bars to slide in or out.

Plate IV. fig. 2 shows the revolution of two magnets round two similar electrified wires *g g*; a stand supported by three pillars *h h h*; *e e* two annular wooden troughs, one is shown separately in section fig. 3; the neck *i* fits easily into corresponding holes in the stand *g g*: *j j* two standards with pointed tops; N S, S N, the two magnets are bent as fig. 4. and have hollows in the middle, by which they swing on the standard points *j j*: fine copper wires *k k* are twisted tight on each magnet, and go loosely round the standards *j j*; they serve to keep the magnets upright; *l* a brass standard fixed at the back of the stand, and bent forwards at top, where it is split to receive the flat piece *m*, which is secured by the screw *o*; this flat piece carries the bent wire *p p*, having cups C C on its shoulders, and points at bottom, to enter without touching the cups *q q*; *f f*, figs. 4 and 5, are bent wires, cemented on the middle of the magnets; these pass through the cups *q q*, and dip into the troughs *e e*, fig. 2; into these, as well as into the cups C C and Z Z, mercury is placed to form the connection, then bringing the galvanic troughs *a a*, and dipping the zinc poles into Z Z at the equators of each magnet, and uniting the copper poles *c c*, by the wires *d d*, to the upper cups C C, the circuits are completed, and the magnets will revolve (as shown by the arrows) around the wires *p p*.

Fig. 6 a horse-shoe magnet, mounted with two mercurial troughs *r r* (fig. 7. shows one separate), *t t* two

cylinders suspended on the ends of the magnets, by points within their crowns under the cups *v v;* their bottom edges are filed away, leaving only four points (as fig. 8) to touch the mercury, by which means the friction is much lessened. The troughs are adjusted by the screws *u u* so as to bring the mercury just in contact with the points of the cylinder; the screw points of the upper cups C C just touch the mercury in the cups *v*. Upon making the communications as before with the cups Z Z and C C, the cylinders will revolve as shown by the arrows.

Fig. 8, *w* is one of the wires which holds the upper cups C C; the bent end *w* twists into a hole in the side of the trough *r*, and thus supports the wire when it is necessary to turn it over on one side previous to removing the cylinders.

Fig. 9 shows a stand on which a rectangular wire is suspended on one of its sharp pointed and amalgamated ends, which is here the copper end; the other or zinc end, although tied to it, is kept separate by the silk thread passing between them, this zinc end dips into the little mercurial cup *x*, from which the small wire *z* descends to the cup Z at bottom, the cup C is united to the standard, (the cup *x*, and the part of the standard that rises through it, is well varnished to insulate the mercury from the standard); on making the zinc and copper communication with these cups the circuit is completed through the rectangular wire, and it will then take the position east and west; but in changing the communication the west side will go round to the east.

Fig. 10 shows another rectangular wire through which the circuit is completed; the side *y* when offered to the west side of fig. 9 repels it, the current being in con-

trary directions through them, as shown by the arrows, but it will attract the east side, the two currents being then alike.

Fig. 11 is a compound or double horse-shoe magnet, fixed upright in a block of wood *a a*. Two brass tubes shown in section *b b*, are fixed in the board *c c*, and fit on over the magnet, making them appear as two pillars; they are secured to the bottom block *a*, by two screws *d*. On the top of these are fitted the two circular mercurial troughs *e e* (they are shown separate in figs. 12 and 13). The upper cups C C have loops, or eyes, at the bottom of their screws, which are amalgamated as well as the hooks of the wires on which the pith balls *f f* are placed. The lower ends of the wires dip into the mercury in the troughs *e e*: on making the communication, or circuit through Z C, Z C, the wires will revolve as shown by the arrows. The upper cup C is insulated from the arm *w*, fig. 13, by the piece *u* being of hard wood.

Fig. 14 shows one of a pair of troughs fitted to the same magnet, it has a fixed arm or arch *g*, through the top of which passes a cupheaded screw, also a smaller arm with the stud *h*, to hang on the top of the pillar *b*, fig. 11. The trough is varnished, to enable it to hold dilute acid. On the stud *h* hangs the zinc cylinder shown separate fig. 15. It is adjusted by bringing the screw in the arch *g* to touch the mercury in the little cup, then the copper cylinder, fig. 16, is hung on the screw-head by its amalgamated point, completing the circuit through the screw of the fixed arch *g*; on filling these vessels with dilute acid the zinc and copper cylinders will revolve as shown in fig. 17.

Fig. 18 shows two of the connecting wires separate, three or four pairs of each of these are required.

These figs. are nearly one-fifth of the real size, and it will be seen that the magnetic power is very great in proportion to the galvanic power.

No. IV.

MODE OF PRESERVING LIME-JUICE.

The THANKS of the Society were this session voted to Captain T. M. BAGNOLD, for his Experiments on preserving Lime-Juice.

IT is well known that the juice of lemons, or of limes, expressed from the fruit, will in a short time, especially if kept warm, become mouldy, and unfit for use as an article of food; and that the final result of this spontaneous change is the destruction of the acid itself. The acid may, indeed, be separated from the other matters with which it is naturally mixed; but in so doing all the odour and flavour of the native juice are also destroyed, for pure crystallized citric acid is wholly inodorous, and to the taste simply acid.

The effect of pure citric acid in preventing or mitigating the severity of sea-scurvy is greatly inferior to the recent juice; and in many of our circumnavigations, lemon or lime-juice, mixed with a small proportion of rum, about one-tenth, has been found to keep for a considerable time in tropical countries, and to be very efficacious in preserving